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AIRCREW TRAINING REQUIREMENTS FOR NAP-OF-THE-EARTH FLIGHT

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In nap-of-the-earth (NOE) flight a helicopter moves at less than treetop height and at variable airspeeds, using natural features for concealment--a dangerous procedure requiring great skill in flying and in navigation. This report identifies specific areas in which NOE training might be improved.

Information from agencies and operational units provided data for analysis of NOE mission requirements, aircrew task analyses, and performance requirements for emergencies. Training objectives derived from the analyses

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20. were verified, compared with existing NOE training programs, and used to suggest improvements.

Problems in navigation and orientation are the major hazard in NOE flight and training improvements should concentrate in these areas. Suggestions for ground-based training aids are visual (cinematic) simulation, a map-interpretation manual for NOE use, and techniques of ground-level orienteering. Suggestions for flight-based training are procedures such as more practice in re-orientation, equipment such as map displays, and policies such as flying over more varied terrain.

Results of the analyses were validated by ARI's field research program and used as the basis for developing the experimental Map Interpretation Terrain Analysis Course (MITAC) now being evaluated at the Army Aviation School, Fort Rucker, Alabama.

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FOREWORD

Within the Army Research Institute for the Behavioral and Social Sciences (ARI), the Human Adaptability and Organizational Effectiveness Technical Area performs research to improve the performance of groups in a variety of military systems and operational units. Programs in the Technical Area include research in human sensory, motor, perceptual, and cognitive factors, and effects of stress and degradation of sensory cues--in this case, the problems of helicopter crews flying at nap-of-the-earth (NOE) altitude (i.e., below treetop level) to evade detection.

This report identifies specific areas in which NOE training for aircrews can be improved; the detailed task analyses and training objectives from which the conclusions were drawn are tabulated in ARI Research Memorandum 76-2, while a review of aircrew training technology done for this project by Dr. Stanley N. Roscoe of the University of Illinois Institute of Aviation has been published as ARI Research Problem Review 76-3. This project was done in close cooperation with the Army Aviation School at Fort Rucker, Alabama; the contributions of military personnel there and elsewhere are gratefully acknowledged. Further studies of human resources in aviation, including flight training selection, simulation, and NOE training, are being done by the ARI Field Unit at Fort Rucker.

ARI research in aircrew performance is conducted as an in-house effort augmented by contracts with organizations selected as having unique capabilities for research in this area. The present study was conducted jointly by personnel from ARI and Anacapa Sciences, Incorporated of Santa Barbara, California, under the direction of Dr. David Meister of ARI; Mr. Gainer was at that time with Anacapa. The entire project was conducted under Army RDTE Project 2Q162107A745; FY 73 Work Program, and 2Q764715A757, FY 1974 Work Program, in preparation for responding to special requirements of the Assistant Chief of Staff for Force Development and the U.S. Army Training and Doctrine Command.

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AIRCREW TRAINING REQUIREMENTS FOR NAP-OF-THE-EARTH FLIGHT

BRIEF

Requirement:

To identify areas in which nap-of-the-earth (NOE) aircrew training at the entry and unit levels might be most readily improved, as part of development of an NOE training course at the Army Aviation School, Fort Rucker, Alabama.

Procedure:

To define the training objectives, deficiencies, and areas of improvement in NOE training, an ordered series of analyses was performed. Information was obtained from agencies and operational units directly concerned with NOE operations; this information provided data for an analysis of NOE mission requirements and aircrew tasks. The mission task analysis was structured progressively from the most general level (battle scenario) to the most specific level (explicit task requirements). A special analysis defined the performance requirements associated with NOE emergencies and contingencies. Analysis of operational requirements resulted in the specification of 1,078 aircrew tasks and 23 contingency performance requirements. Training objectives were derived from these, verified by operational personnel, compared with objectives of existing NOE training programs, and, together with results of a parallel review of flight training technology, used to suggest improvements for NOE aircrew training.

Findings:

Because navigation and orientation provide the chief problems during NOE flight, improved training in these areas should provide the greatest gain in total pilot proficiency. Suggestions for ground-based training aids are visual (cinematic) simulation, a map-interpretation manual designed for NOE use, and techniques of ground-level orienteering. Suggestions for flight-based training are 1) procedures such as more practice in re-orientation and use of maps showing only natural features, 2) equipment such as map displays, and 3) policies such as choosing flight paths that fly over a wider variety of terrain..

Some of the other aspects of NOE training may be appropriately aided by classroom or computer-aided instruction, some by simulation, and some appear to require actual flight training. In mission planning, computer-aided instruction could help develop judgmental skills, and techniques for map memorization could be taught in the classroom. Practice with simulators could improve procedural skills in communications. However, actual flight time appears necessary to develop procedural and manual skills for aircraft handling in NOE flight and maneuvers, including emergency procedures such as NOE recovery maneuvers. Visual surveillance also appears to be a unitary skill best developed during flight, requiring as it does both "head up" scanning for navigation and threat detection and "head down" scanning to monitor displays and read maps.

Utilization of Findings:

The results of these analyses were validated by the results of ARI's field research program. This combined effort of analytical and field research was then used as the basis for development of the experimental Map Interpretation Terrain Analysis Course (MITAC) now under evaluation at the Army Aviation School.

AIRCREW TRAINING REQUIREMENTS FOR NAP-OF-THE-EARTH FLIGHT

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INTRODUCTION

Study Purpose

The purpose of this study was to assist the Army in identifying and developing potential improvements in nap-of-the-earth (NOE) training at the entry and unit levels. To accomplish this purpose we sought to derive statements of NOE training objectives based on a detailed analysis of mission requirements and aircrew tasks, and to identify the most promising methods of improving training to meet those objectives. This report describes the technical approach and methods of the study, the results obtained, and our conclusions and recommendations.

The tactic that has become known as nap-of-the-earth flight is not new to Army aviation. It evolved from airmobile and air assault concepts that were developed and evaluated in the early 1960's. However, the increased sophistication of enemy air-defense weapons, including heat-seeking missiles and radar-directed automatic weapons, has brought about a renewed emphasis on NOE flight. Although NOE flight was seldom needed during the conflict in Southeast Asia, most Army aviation authorities agree that NOE flight will be a mandatory tactic in future combat environments.

In Training Circular TC-1-15,[1] nap-of-the-earth flight is defined as:

> "Flight as close to the earth's surface as vegetation or obstacles will permit, while generally following the contours of the earth. Airspeed and altitude are varied as influenced by the terrain, weather, and enemy situation. The pilot preplans a broad corridor of operation based on known terrain features which has a longitudinal axis pointing toward his objective. In flight, the pilot uses a weaving and devious route within his preplanned corridor while remaining oriented along his general axis of movement in order to take maximum advantage of the cover and concealment afforded by terrain, vegetation, and man-made features. By gaining maximum cover and concealment from enemy detection, observation, and firepower, nap-of-the-earth flight exploits surprise and allows for evasive action...."

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[1] Headquarters, Department of the Army. Training Circular TC-1-15, 1973.

This mode of flight is illustrated in Figure 1 and is differentiated from either contour flying or low-level flying, which are defined in TC-1-15 as:

> "Contour Flying. Flight at low altitude conforming generally, and in close proximity, to the contours of the earth. This type flight takes advantage of available cover and concealment in order to avoid observation or detection of the aircraft and/or its points of departure and landing. It is characterized by a constant airspeed and a varying altitude as vegetation and obstacles dictate."

> "Low-Level Flying. Flight conducted at a selected altitude at which detection or observation of an aircraft or of the points from which and to which it is flying, is avoided or minimized. The route is preselected and conforms generally to a straight line and a constant airspeed and indicated altitude. This method is best adapted to flights conducted over extended distances or periods of time."

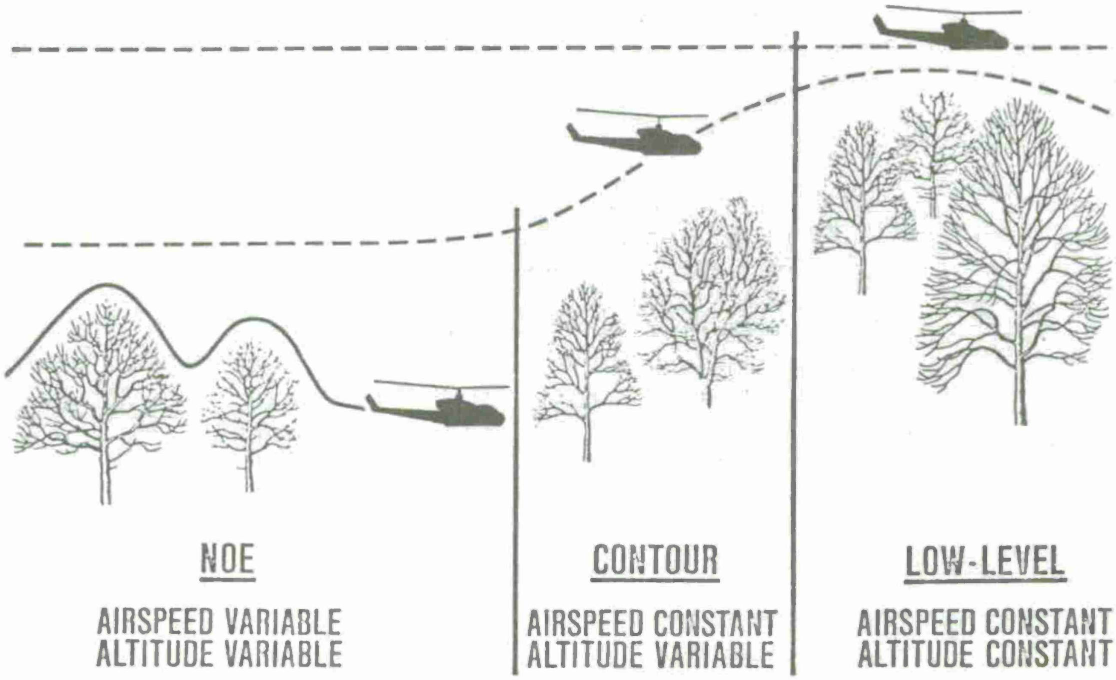

Figure 1. Illustrations of the distinctions between nap-of-the-earth flight, contour flight, and low-level flight (from HQDA TC-1-15, 1973).

An improved NOE training program must proceed from a detailed statement of aircrew performance requirements. The general definitions given above do not suffice. Since no detailed statement of requirements existed, the study reported here was undertaken.

Approach

The approach taken in this study can be decsribed most simply as a series of surveys and analyses to determine current doctrine and practice in NOE operations; define NOE mission requirements and specify aircrew tasks in NOE flight; derive NOE training objectives, verify the operational validity of the training objectives, and compare current NOE training programs to the verified objectives; assess the applicability of training technology; and assess the impact of new system developments on NOE training. From the findings of these surveys and analyses, potential improvements in NOE training were identified and recommended for development and implementation.

The scope of the study was restricted to daylight NOE operations, because the methods, equipment, and tactics to be employed in night operations or in foul weather are under development and changing rapidly. We believed that an intensive analysis of aircrew performance in daylight, visual flight rules (VFR), tactical helicopter operations would serve the immediate need and would provide a meaningful point of departure for future studies of night operations.

Following are brief descriptions of the main steps in the study.

Survey of NOE Operations. The study began with a review of the available literature on NOE research, training, and doctrine. Then a series of visits was made to the principal Army training organizations, research and development agencies, and operational units that were directly concerned with, or had special knowledge of, NOE operations in the Army. During these visits, interviews and discussions were conducted with more than 80 persons from 18 organizations. The information obtained in these interviews served to structure the analysis of mission requirements and aircrew tasks, and helped us gain an understanding of the current practices, developments, and constraints in NOE operations. Throughout the project, we maintained contact with the operational personnel at the visited sites, who provided many of the key inputs to the analyses that followed.

Analysis of NOE Mission Requirements and Aircrew Tasks. The expected role of Army aviation in combined arms operations in a mid- to high-intensity conflict was projected from the available Army doctrine and from the survey information. The characteristics and requirements of missions involving NOE flight were defined and representative mission profiles were derived. A detailed analysis of the functions and tasks required of Army helicopter crews in NOE operations was performed to provide the essential data base for identifying training requirements.

The method is described in the Technical Supplement. The resulting task analysis is published separately.[2] Although the task analysis was performed as a means to the specific ends of this study, the results constitute a significant general contribution to the literature on helicopter aircrew performance and will be useful in several other research applications.

Specification of NOE Training Objectives. The detailed task descriptions were analyzed to derive specifications of the training objectives that would have to be met to achieve aircrew proficiency in NOE operations. The task analysis results and the derived training objectives were delivered to the personnel of the Army research and training organizations and the operational units that had participated in our initial survey. They reviewed both sets of data and verified the accuracy and operational relevance of the findings. They made several corrections, changes, and improvements which were incorporated into the results presented in this report. Concurrently with the analysis of aircrew tasks and training objectives, we reviewed the present Army NOE training programs. The training objectives of the present programs were compared with the training objectives that were developed from the steps described above to define areas where training improvements may be warranted. The procedures for specifying the training objectives are described in the Technical Supplement, and the training objectives themselves are published separately.[3]

Review of Training Technology and System Developments. We reviewed the available and potential training devices and techniques that might be applied to NOE flight training.[4] The known or predicted effectiveness of various training techniques and devices was assessed with respect to the verified training objectives, and with respect to the constraints of the Army aviation training environment. We also attempted to gain some insight into how the training objectives identified in this study might change in the near future. To this end we reviewed significant developments in helicopter systems and equipment and attempted to assess their potential impact on NOE operations and training requirements. The main conclusions and recommendations are presented here.

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[2] Gainer, C. A., and Sullivan, D. J. Aircrew task analysis and training objectives for nap-of-the-earth flight. ARI Research Memorandum 76-2, February 1976.

[3] Gainer and Sullivan, 1976, op. cit.

[4] Roscoe, S. N. Review of flight training technology. ARI Research Problem Review 76-3, July 1976.

RESULTS AND CONCLUSIONS

An analysis of operational requirements resulted in the specification of 1,078 aircrew tasks and 23 contingency performance requirements, which provided the data base for identifying the training objectives that would have to be met to achieve aircrew proficiency in NOE operations. The implications of these task data are discussed in this section in conjunction with the derived training objectives and potential improvements in NOE flight training. The discussion below is organized in terms of nine main classes of training objectives: (1) navigation and orientation (2) mission planning, (3) aircraft handling, (4) visual surveillance, (5) crew coordination, (6) communications, (7) emergency procedures, (8) tactical employment, and (9) systems management. The order of presentation does not imply a recommended training sequence, but follows our general view of the hierarchy of problem areas as they relate to potential improvements in NOE training.

NAVIGATION AND ORIENTATION

Requirements

The most dramatic difference, in both degree and kind, between the skills and knowledge required for NOE flight and those required for flight at altitude was found in the tasks of navigating and maintaining continuous, accurate geographic orientation. The skills required for navigation and orientation at high altitude in a benign environment are virtually irrelevant in NOE operations. The NOE aviator must acquire a new set of skills involving accurate terrain analysis, precise pilotage in a highly restricted visual field, and valid map interpretation. The development of these unique skills may be considered the cornerstone of NOE training.

Successful navigation is extremely difficult under NOE flight conditions for a variety of reasons which have long been recognized. The main problem is that pilots, to navigate and maintain geographic orientation at minimum terrain clearance altitudes, must learn to interpret and adapt to a unique visual world. The relevant characteristics of this world include:

> <u>a greatly restricted geographic area of view</u>, which limits the range at which a ground feature can first be seen and shortens the period of time it will remain in view;
>
> <u>terrain and vegetation masking</u>, which occludes significant portions of the visual world;
>
> <u>a sharply oblique view of the terrain</u>, which conflicts with the planimetric presentation used on all topographic maps;

a highly dynamic visual scene, which complicates the perception of spatial relationships;

a high relative velocity of objects in the visual field, which increases the difficulty of checkpoint and target detection;

a large visual scale of perceived ground objects, which conflicts with the small scale of their cartographic counterparts; and

enhanced significance of features with relief or vertical development, which must be correlated with maps which emphasize features with extensive horizontal development.

The NOE pilot must learn to deal with this visual environment so efficiently that he can simultaneously perform a variety of aircraft control tasks, monitor the cockpit displays, communicate, and manage the avionics and weapons systems.

In addition to the characteristics of the visual environment which make geographic orientation extremely difficult, NOE navigation is complicated by other problems. First, the pilot must rely almost entirely upon visual pilotage (navigation by correlating features observed in the real world with those portrayed on the map) and cannot effectively use dead reckoning techniques nor radio aids. Second, NOE navigation demands head-up performance in which glances inside the cockpit typically last no more than a few seconds, so that the pilot must rely heavily on map recall. Third, the maneuvers required in NOE operations produce continuous changes in heading, speed, altitude, and attitude, so that the velocity vector of the aircraft is rarely constant for more than a few moments. Fourth, the NOE navigator is forced by the head-up requirement and lack of automatic navigation equipment to rely largely on rule-of-thumb procedures enroute. Finally, Army aviation missions may require rapid responses in launching and executing NOE operations, which will reduce the opportunity for navigation planning. Wright and Pauley,[5] in their study of Army low-level navigation during the mid-1960's, and Saathoff,[6] in his more recent study, cited these and other problems.

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[5] Wright, R. H., and Pauley, W. P. Survey of factors influencing Army low-level navigation. Alexandria, Virginia: Human Resources Research Organization, HumRRO-TR-71-10, 1971.

[6] Saathoff, D. I. Initial entry and unit training requirements for nap-of-the-earth helicopter flight. In Aircrew performance in Army aviation. Proceedings of U.S. Army Office of Research, Development, and Acquisition conference, November 27-29, 1973, Army Aviation Center, Fort Rucker, Alabama, 1974.

The importance of navigation and orientation skills in NOE training is reflected in the present Initial Entry Rotary Wing NOE curriculum and in the guidelines for unit-level NOE training given in TC-1-15: about one-half of the allocated flight hours are devoted to navigation training. In view of the uniqueness of NOE navigation tasks, the difficulty of performing them, and their prominent role in the NOE curriculum, the greatest gains in total pilot proficiency in NOE flight are most likely to come from improvements in navigation and orientation training.

Dominant Training Objectives

The task analysis results and the derived training objectives clearly showed that the skills required for NOE navigation are primarily visual-referencing skills--the ability to relate features in the real world to their cartographic counterparts. Other aspects of NOE navigation, such as reading digital coordinates, course determination, and range estimation, are important but much less difficult to teach. Therefore, training should focus on developing the skill and knowledge that the aviators need both to identify on the map features seen in the real world and to identify in the real world features preselected on the map. This means that the aviator must be able to predict and correlate information from the world as seen in the NOE environment with information on the map, and vice versa.

No textbook or lecture alone can teach an aviator to deal with the visual phenomena of extremely low-altitude flight. Consequently, NOE navigation training has centered around flight training. But flight training is expensive, depends on good weather and the availability of aircraft, and usually requires an instructor-to-student ratio of 1:1. Moreover, because of the limited number of flight hours available for training and because of the many other demands on the attention of both instructor and student during NOE operations, flight training can rarely be devoted to navigation and orientation alone. The result is that the student is so preoccupied with aircraft control and communication tasks during the early phases of NOE flight training that he has little attention to spare for acquiring visual-referencing skills, and normally perfects them only after scores--even hundreds--of hours of NOE flight experience. The present allocation of 12 flight hours to Initial Entry NOE training is not adequate flight time to develop these skills, and should be increased, probably doubled. But we believe that cost-effective improvements in NOE navigation training are not likely to be gained from increasing the number of flight hours alone. The training process would be best expedited if some of the visual skills could be acquired through suitable ground-based training. Therefore, our suggestions in this area emphasize improvements that can be made in NOE academic training.

Visual Training Aids. Visual skills must be taught with visual training materials. The visual skills required in NOE navigation and orientation must, therefore, be taught by using materials that reproduce or clarify the relevant aspects of the visual environment as seen from very low altitude. At present, visual training aids available to NOE instructors are limited largely to 35-mm slides of significant terrain features, some video tapes recorded during NOE flights, and some limited motion-picture footage of poor quality. These materials are not sufficient to the need.

In recent years, important advances have been made in the development of visual flight simulators, none of which has been applied to NOE training. Therefore, we reviewed the state of the art in visual flight simulation to assess its potential application as a supplement to NOE flight training. We found that a high-fidelity, closed-loop visual simulation of the full NOE navigation task is not within the current simulation art.[7] However, open-loop cinematic simulation employing high-resolution, wide-angle, color films may provide a cost-effective means for teaching helicopter pilots some of the visual skills required for geographic orientation during NOE flight.

The principal limitations of cinematic methods of flight simulation are resolution, field of view, and predetermined flight path. The image resolution that can be attained with modern films and projection systems is "limited" only in the sense that it is less than the resolving power of the human eye directly observing the field of interest. Any other method of simulating the visual field, such as TV/terrain-model techniques, produces an image of much poorer resolution. Assuming that the cinematic simulator reconstructs the geometry of the visual field so that objects in the projected image bear valid angles from the observer, the best resolution of the image would be about five minutes of arc. This is not sufficient resolution for training in NOE target-acquisition task but is quite adequate for training in geographic orientation and map interpretation.[8]

Cinematic simulators are limited in field of view only to the extent dictated by economics. A full 360° field of view can readily be simulated, but if maximum image resolution is to be retained and image distortion is to be avoided, a multiple-projector system is needed. Not only is the projection system complicated, but the screen must be a

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[7] Roscoe, 1976, op. cit.

[8] McGrath, J. J. The use of wide-angle cinematic simulators in pilot training. Orlando Florida: Naval Training Equipment Center, Technical Report NAVTRAEQUIPCEN 70-C-0306-1, Task 1799-03, 1973a.

section of a sphere and only a few observers (theoretically only one) can be presented a valid simulation at any given time. For more practical classroom presentations of filmed materials, the maximum field of view that can be attained distortion-free on a flat screen is slightly less than 90°.

The main limitation, though, is that cinematic simulators present a predetermined flight path, which is to say that the observer must go where the photography aircraft went. Although cinematic simulators can provide closed-loop control of pitch, roll, yaw, and speed, the three translational degrees of freedom are fixed by the film.[9] Therefore, cinematic methods do not permit students literally to navigate. Nevertheless, a large number of training objectives can be met in spite of the open-loop nature of cinematic simulation.

Some of the fundamental skills and knowledge needed for geographic orientation at NOE altitudes involve detecting and identifying various types of preselected navigational checkpoints, judging distances, seeking mask, interpreting terrain forms, relating sighted features to those portrayed on the map, and making navigational decisions. Training exercises designed to impart such skills and knowledge have been designed using open-loop cinematic materials and part-task training methods and successfully applied to training Navy pilots in high-speed, low-altitude navigation.[10] The application of cinematic methods to training NOE pilots is at least equally promising.

An adequate library of wide-angle films, accompanied by properly developed instructional procedures and practical exercises, would have many potential uses in navigation and orientation training. Primarily, these materials could be used to introduce the student to the NOE visual environment by demonstrating the impact of masking effects, oblique angles, brief exposure times, and dynamic geometry on the visual field at very low altitudes and on the appearance of navigational checkpoints.

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[9] With extreme wide-angle (160° or more) systems, a limited simulation of cross-track translation can be achieved, but it is useful only for simulating approaches or other maneuvers where the velocity vector does not significantly change.

[10] Borden, G. J. Training pilots in the use of aeronautical charts: a conference report. Goleta, California: Human Factors Research, Inc., Technical Report 751-15, 1968.

McGrath, 1973a, op. cit.

McGrath, J. J. Chart interpretation in low-altitude flight. Orlando, Florida: Naval Training Equipment Center, Technical Report NAVTRAEQUIPCEN 70-C-0306-2, Task 1799-03, 1973b.

Practical exercises can readily be developed to give the student practice in some of the problems of map interpretation in a dynamic mission context. In addition, the materials can extend the student's experience by demonstrating the changing appearance of the world, and the changing orientation strategies required, in different geographical regions and under different climatic or seasonal conditions. Elaborate simulation techniques are not required for most of the specific points of instruction, so the cinematic materials can be adapted either to classroom use or to highly simplified, rear-projection, visual-field simulators. Therefore, cinematic simulation can feasibly be applied to both initial entry and unit level training.

NOE Map User's Manual. In addition to the need for cinematic training materials, there is a serious need for a special instructional text on map interpretation that is specifically tailored to the NOE use of maps. This map user's manual must be more than an extended description of a map legend and a discussion of how to plot courses and read coordinates. The manual should be specifically designed to familiarize aircrew personnel with those characteristics of topographic maps and other earth-reference graphics which influence their performance in map interpretation and navigation at NOE altitudes.

A special manual for NOE map users is needed mainly because cartographers apply a great many conventions and selection criteria in compiling any kind of map which have a direct impact on the user's ability to interpret the information shown on the map. However, few map users, even highly experienced pilots, know what these conventions and criteria actually are. For example, the selection and classification of roads, the portrayal of vegetation cover, the use of shaded relief and contouring methods, the grouping of cultural features under conventional symbols, generalization and offsetting practices in cartographic drafting, the geodetic accuracy limitations, the seasonal base, and many other factors in the compilation of a topographic map are all largely unknown to Army pilots. This information is not found in Army map legends or existing texts on map reading. Yet, without such knowledge, accurate map interpretation cannot be performed. Therefore, in developing an NOE user's manual, information must be obtained directly from the Defense Mapping Agency on the conventions and criteria that went into the compilation and design of each relevant map class, including at minimum the 1:50,000 Air Movement Data map, the 1:250,000 Joint Operations Graphic, and at least one representative image-based pictomap or orthophotomap product. The information from the cartographers must then be translated into the terms and examples that are most meaningful to the Army NOE aviators. This basic text on map interpretation as it applies to NOE flight would provide much of the instructional foundation for the cinematic training exercises in geographic orientation.

Terrain Walk. The next logical step is to instruct and exercise the student in geographic orientation in the real world, but without requiring actual flight. The most promising non-flying method of teaching geographic orientation and map interpretation is the terrain walk, where the student, with map and compass, navigates a course on foot. In the terrain walk, the time and workload constraints on NOE

navigation are largely removed and the student can concentrate on terrain analysis and relating the real world to the map. This training technique has the additional advantage of familiarizing the pilot with the field conditions that confront the ground forces with whom he must work. The terrain walk also permits the student to exercise his orientation skills, in the real world, in populated areas where current flight restrictions prevent flight training. Orienteering competitions, blind drops, and other procedures can be added to stimulate motivation and present challenging map-interpretation problems.

The terrain walk technique has two important limitations that should be addressed in an improved training program. First, the procedure is time-consuming (it can also be exhausting, but beneficial to physical conditioning); second, the "altitude" is too low. Terrain walks could readily be made less time-consuming by employing motorized trail bikes. These vehicles cost less than $500 each, are easy to operate, and their use would either extend the practical range of terrain-walk exercises or would reduce the time required to negotiate a particular course. The use of trail bikes would not, of course, solve the altitude problem. Possibly, jeeps or trucks with elevated platforms for observers might be useful in providing students with a better approximation of the view from NOE operating altitudes, at least in training areas where ground vehicles can move with reasonable freedom.

Potential Improvements in Noe Flight Training

Flight training in NOE navigation and orientation also needs improvement, but the potential for improvement is much more limited than is the case with academic or ground-school training. It is important to realize that, while flight training is ultimately essential to the development of the required skills, its effectiveness depends heavily on how much the student has already learned in ground school. Consequently, improvements in the academic curriculum will in themselves produce improvements in flight training by allowing the flight hours to be devoted largely to integration and application of skills and knowledge, rather than to elementary instruction.

Improvements in NOE flight training can be achieved mainly by improving procedures, equipment, and routes. We have few suggestions to offer concerning procedural improvements, because the current training procedures themselves vary widely among instructors and units. However, following are some general observations.

Procedures. Experience in training attack pilots to navigate accurately in high-speed, low-altitude flight has shown that pilots learn more about map interpretation, terrain analysis, and route selection when they have ample opportunity to navigate while precisely and continuously oriented. Other than experiencing the despair and frustration of disorientation at low altitude (which in itself may be an important part of flight training) and gaining a convincing demonstration of the difficulty of the NOE navigation task (also important), the student learns very little when he is lost. Consequently, and aside from

safety considerations, the instructor pilot should make every effort to ensure that the student is precisely oriented at all times during his initial exposure to inflight NOE navigation. Generally, this means that more definitive guidelines are needed for instructors in their decisions to direct, cue, or otherwise "help" the student. We recommend that after the student's first experience with geographic disorientation, which may be permitted for motivational purposes within safety limits, the instructor pilot should provide maximum direct assistance in geographic orientation during at least the first two hours of flight training in NOE navigation.

Flight training procedures in NOE navigation and orientation should incorporate ongoing exercises of the student pilot's ability to anticipate the terrain, both in terms of its appearance or checkpoint content and in terms of passage of time or arrival time. All experienced pilots regularly attempt to obtain a preconception of what checkpoints or targets will look like. Indeed, preconception of the terrain ahead is almost unavoidable, but it is a two-edged sword. If correct, preconception will assist the pilot to detect and recognize a checkpoint; if wrong, it will hinder detection and recognition.[11] One of the most important objectives of training in navigation planning may well be training in achieving accurate preconceptions from map and photo study. However, such training requires reinforcement to be effective; that is, the pilot must have an opportunity to find out whether or not his preconception was correct. While this can be accomplished to some extent through cinematic simulation, the best opportunity occurs during actual flight. Consequently, the instructor pilot should call for estimates or predictions of checkpoint visibility ranges, unmask points, transit times, arrival times, physical characteristics of features portrayed on the map, spatial patterns of features, vegetation characteristics, and the like. These estimates and predictions of features ahead should be made at every opportunity and then confirmed or refuted when the feature is reached (or missed).

We also suggest that some provision be made for inflight practice of reorientation techniques, especially as a part of advanced unit training. Such practice and instruction is provided in the current programs, but usually on an ad hoc basis--that is, when geographic disorientation happens to occur. Skill in reorientation is sufficiently important that specific training in these methods should be explicitly planned and included in the training program. This would probably involve a series of blind insertions at points previously selected by the instructor pilots, but unknown to the student pilots. The points should be selected to provide clear illustrations of different reorientation techniques, such as the use of navigational funnels, barrier features, hypsography, and drainage azimuths. This training must be closely tied

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[11] McGrath, J. J. and Borden, G. J. Geographic orientation in aircraft pilots: a problem analysis. Goleta, California: Human Factors Research, Inc., Technical Report 751-9, 1963.

to map-interpretation instruction. For example, a knowledge of the classes of features to which cartographers apply a 100% selection criterion is a prerequisite to skill in reorientation.

Another procedural improvement would be to develop an assessment method whereby the student can relate his navigation performance to his success in remaining masked. The very reason for flying NOE in the first place is to gain maximum concealment from visual and radar observation by enemy forces, to gain maximum cover from enemy firepower, and to exploit the advantage of surprise in offensive operations. NOE navigation performance cannot be fully assessed by track deviation errors, checkpoint acquisition rates, coordinate position fixes, and similar measures alone. Some index of exposure, or potential exposure, is needed not only to give operational meaning to the navigational performance measures, but to impress upon the student the need to stay low. To put this point in different language: the NOE pilot must learn to make a fundamental trade-off between navigational considerations (the lower he flies, the more difficult it is to remain oriented) and masking considerations (the higher he flies, the more likely he will be discovered); and to fully understand this trade-off he needs knowledge of results in both criteria. Post-flight debriefing practices now seem to emphasize navigational performance, which usually is reconstructed by plotting the track made good and comparing it with the planned track.[12] What is missing is a good index of the aircraft exposure time and range along the track. A practicable and simple method of obtaining such an index needs to be developed and used at least in debriefing, ideally in real time during the training flight. The application of computer graphics, described in the following discussion concerning training in preflight planning, is one possibility; the use of "adversary" observers in the field in another. At least, instructor pilots can explicitly record their estimates of exposure rates and ranges.

Equipment. Potential equipment improvements in flight training of NOE navigation skills are confined to displays and maps. First, the Army should study the potential value of automatic map-display systems as training devices. The use of map displays as operational equipment in Army aircraft is a different and more complex issue, which cannot appropriately be addressed in this report. The idea we wish to introduce here is the use of map displays during initial NOE navigation training as a possible means of promoting faster learning of NOE map-interpretation

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[12] While this practice itself might be improved by more objective procedures, experienced pilots are remarkably accurate in post-flight reconstruction of ground tracks. Borden and McGrath found the average coefficient of correlation between pilots' recalled tracks and objectively measured tracks on the same missions to be .90.(Borden, G. J., and McGrath, J. J. Geographic orientation in aircraft pilots: field validation of a post-flight method of reporting navigation performance. Goleta, California: Human Factors Research, Inc., Technical Report 751-14, 1968).

skills, even though such displays are not part of the normal complement of avionics in current Army aircraft. The presence of a well-designed, properly calibrated map display would prevent student aviators from becoming grossly disoriented during their early training in NOE navigation. The student should be better able to maintain the required accuracy of geographic orientation during introductory NOE navigation training, and this condition should lead to a more rapid development of map-interpretation skills. Experimental studies[13] have shown that the availability of an automatic map display during initial flight training also expedites the attainment of skills in aircraft control and tactical maneuvers by improving orientation and lessening the workload of the student pilot. To avoid misunderstanding of this point, we repeat that the potential role of map displays as training devices is during the early portion of the NOE navigation training program. The student must ultimately learn to navigate without any aids other than a hand-held mission-annotated map. The initial aiding by a map display, like "training wheels" on a bicycle, would be a temporary assist to promote a quicker understanding of the map-interpretation techniques required at NOE altitudes.

Training improvements might be made with respect to the maps used by the aviators. Present training in NOE navigation is conducted almost exclusively with a conventional 1:50,000-scale topographic line map and, in limited areas, with the experimental Air Movement Data graphic. Map-interpretation skills developed with these products will not necessarily transfer to the use of other map forms which the pilot may eventually have to use in planning and executing a mission. These other types include image-based products such as photomaps, orthophotomaps, pictomaps, and orthopictomaps; line maps of different scale factors such as military city maps and Joint Operations Graphics; and plastic relief maps. In addition, when operating in foreign areas, the pilot may have to use maps that were developed from the cartographic resources of other countries. In spite of international standards, there are major differences in compilation and portrayal methods, which the pilot should at least be familiar with. Also, the map coverage of virtually all NOE training areas is of the Class A-1 quality of accuracy and currency.[14] Yet in operational practice, particularly in the event of foreign war,

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[13] Carel, W. L., McGrath, J. J., Hershberger, M. L., and Herman, J. A. Design criteria for airborne map displays, Volume I: Methodology and research results; Volume II: Design criteria. Culver City, California: Hughes Aircraft Company, Technical Report HAC REF NO. C2151-003, 1974.

[14] This criterion class refers to map sheets in which 90% of the planimetric features (except those displaced to accommodate exaggerated size of symbols) are located within 0.02 inch of their correct position with reference to the map protection and are sufficiently complete and current in their portrayal that no revisions are required.

the pilot may have to use maps of inferior accuracy and currency. We recommend that a portion of the Initial Entry academic training be devoted to instruction in the significant differences among the various map products that the NOE aviator eventually may have to use, and that a portion of the flight training curriculum at the unit level be devoted to this objective.

One of the problems of NOE navigation training might be solved by the use of a special-purpose training map that would focus the pilot's attention on the natural features that serve as his most reliable orientation cues during NOE flight. The problem is this: pilots entering the NOE training program have already developed a set toward the geographic orientation practices that they have learned through predominantly high-altitude flight experience. A common tendency is to look mainly for cultural features, such as roads, towns, bridges, and other manmade objects, as the primary cues to geographic orientation and to use natural features, such as landforms and drainage, as secondary cues that may help identify the manmade checkpoints. This practice or set, which is entirely contrary to the orientation strategy needed during NOE flight, can be an important impediment to the development of skill in NOE navigation and is not readily overcome by lectures and exhortations. We recommend that a study be made of the utility of a special purpose training map which portrays only four classes of features: terrain elevation values and contours, hydrographic features, vegetation, and Universal Transverse Mercator (UTM) grid. The student could be required to plan and execute an NOE navigation training mission using only this map. The student, perforce, must then rely upon natural features for orientation, because no other information would be available to him. He could, of course, see cultural features in the real world, but he would be unable to use them as orientation cues or checkpoints. The experience of attempting to navigate NOE with the natural-feature map would focus the student's attention on the most relevant aspects of the NOE environment. Training could thereafter proceed using conventional maps. The production of this special-purpose map would be entirely feasible and inexpensive, because new compilation plates would not be required.

Routes. The third area of potential improvements in flight training of navigation skills concerns the available real estate or routes over which NOE flights may be conducted. Present training is restricted to sparsely populated areas and, for a given unit, to homogeneous types of terrain. Initial Entry NOE training is confined to a fairly flat, wooded, mostly unpopulated section of Alabama where the hierarchy of checkpoint features is entirely different from that which prevails in desert or mountainous areas. Some units, such as those in Hawaii, have virtually no areas available for any significant training in NOE navigation. The problem is that while a fully competent NOE navigator should be able to operate in any type of terrain, including Arctic regions, most Army pilots are limited to flight experience in only one or two types of terrain. Obviously, we can do little more than to suggest the need for providing pilots, at least at the unit level, with opportunities to gain NOE flight experience in different types of terrain. Experts in military procedures and logistics are the appropriate persons to devise cost-effective ways of accomplishing that end. At minimum, navigation

training routes can be laid out within the available operating areas to take full advantage of whatever terrain variety the areas offer. Also, the cinematic simulation methods described earlier should be implemented to enrich the pilot's experience, particularly with terrain and climatic conditions found in regions too remote for any feasible flight training program.

Impact of Future Developments. Future developments in navigation systems such as LORAN C/D will have little impact on NOE navigation training as it applies to daylight VFR conditions, because the training objectives must continue to focus on the visual-referencing skills required for geographic orientation. New systems will, of course, bring new requirements to train pilots to understand and operate them; but regardless of the sophistication of navigation sensors, computers, or displays that may be introduced in Army aircraft, the aviator will still be required to master the task of unaided visual pilotage as a backup navigation technique. A few observations are warranted, though, on the impact of map displays on training requirements. Airborne map displays constitute the only class of avionics that directly influences geographic orientation practices, because no other type of display presents directly usable visual-reference data.

If map displays were installed in helicopters flying NOE missions, additional training would be required to instruct aircrews in the operation of the display system and in the preparation of the displayed maps. This training requirement would be straightforward and not much different from the training impact of any new piece of equipment. Aside from this requirement, and the potential role of map displays in introductory training that we discussed earlier, the most important impact on training requirements would be the need for intensive training in the practice of display updating. The effectiveness of a map display is directly dependent upon the pilot's ability to update it.[15] Pilots would have to be trained to perform updating procedures rapidly and accurately while operating NOE, but more importantly they will need training in decision-making. The key to successful navigation with a map display is knowing when to update and when not to update, which in turn requires an understanding of cartographic accuracy, display error probabilities, navigation system inputs, and human performance limitations. If the aviator does not update the system often enough, he can experience geographic disorientation of the most severe and dangerous kind--being lost without knowing it. On the other hand, if he updates too often, or attempts too fine a degree of correction, he is likely to become unncessarily preoccupied with operating the map display and his total performance will suffer. If he adopts the optimum updating strategy, he will gain the maximum benefits of orientation aiding from the display with the minimum cost of workload. The optimum updating strategy will depend upon the display's performance characteristics and upon the mission, but it must be a central part of the navigation training program.

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[15] Carel, et al., 1974, op. cit.

MISSION PLANNING

Closely related to the training objectives for NOE navigation and orientation are the training objectives for mission planning. We have treated them as separate categories for expository convenience and because the former involves the development of visual and procedural skills while the latter involves the acquisition of the technical knowledge that underlies those skills. But training in the two subjects necessarily must be closely integrated.

Requirements

Preflight planning is important to the success of any air operation, but is absolutely vital to the success of NOE operations. In fact, professional skill in mission planning is the essence of success in all types of low-altitude missions. Pilots entering the NOE training program will already have developed skill in many aspects of mission planning, such as the preflight activities dealing with fuel management, the use of meteorological data, communications procedures, and certain navigational calculations. They should also be able to understand mission orders and perform the preflight systems checks that apply to any flight operation. The emphasis of training in NOE mission planning should be focused on two major subjects: route selection or terrain analysis and route study or terrain familiarization.

The general skills required in route selection are analytical and judgmental abilities. The pilot must assess his route options in light of the mission requirements and objectives, the tactical situation, and the terrain characteristics. He must learn to make valid trade-offs between navigational considerations and the need to gain cover and concealment. Characteristically in NOE operations, the routes that would be most easy to navigate are the routes that offer the least cover and concealment; in a hostile environment, the best checkpoints, such as prominent hills, are often the most likely places to encounter enemy defenses; routes that parallel major roads are simple to navigate, but increase vulnerability to acquisition; and so on. These trade-offs, and many others, must be understood and assessed along with other considerations, such as fuel economy, the availability of natural corridors of approach, alternative routes, funnels and barriers to prevent gross deviations from course, restricted areas, and coordination with ground forces and other air units.

The general skills required in route study are those involved in the interpretation and memorization of maps, photos, and other intelligence data. The ability to recognize patterns of relief, vegetation, hydrography, and cultural features is highly important. Further, these patterns must be conceived in terms of the visual restrictions and viewing angles that will prevail, and they must include the temporal patterns--or sequences of features--as well as spatial patterns. Particular skill is needed in selecting valid orienting cues at key points in the mission, such as the letdown or NOE insertion point, the forward

edge of battle area, landing zones, and observation or firing positions. Accurate preconceptions of the appearance of features must be developed, and the essential characteristics and major landmarks of the entire operating area must be committed to memory.

The results of our analysis of training objectives in this subject agree well with the objectives of the current Initial Entry NOE curriculum and with the objectives noted in TC-1-15. The importance of mission planning is heavily emphasized throughout the current program, and there seems to be good agreement among instructor pilots on what needs to be taught. Our suggestions in this area mainly deal with potential improvements in how to teach it.

Route Selection

In spite of the importance of the judgmental skills required in terrain analysis and route selection, student pilots in current NOE training get little opportunity to exercise that skill. Routes for training flights are either specified or so narrowly constrained that few judgments are left to the student. While this restriction might be necessary and acceptable in Initial Entry NOE training, greater flexibility certainly should be sought in advanced unit training.

Much of the learning in this area is conceptual, and present lecture and demonstration methods can suffice. However, there is a potentially powerful role for computer-assisted instruction (CAI), and we strongly recommend that at least a feasibility study of CAI applications be made. The current state of the art in this field is discussed by Roscoe.[16] Generally, the capability exists right now to implement interactive CAI techniques to allow the instructor to present, or students to call up, stored intelligence materials, maps, photographic slides, and printed (or audio) messages, and to construct geometric figures or graphs activated by commands of either the instructor or the student. For example, to develop the student's ability to predict masking effects, the instructor could present the tactical situation on a displayed topographic map and describe the mission objectives. The student, using the CAI system to review and assess intelligence materials, could then specify a route of NOE flight to achieve the objectives, and the candidate route would be displayed on the map. The computer could then, from stored elevation and vegetation contour data, display the changes in masking (a line-of-sight envelope) as the helicopter moves along the route at a designated clearance altitude. This would provide the student with immediate feedback on his success in selecting a route that offers good cover and concealment, and would dramatically highlight any errors in judgment. The student, interacting with the computer, could modify his route to test alternatives and to examine hypothetical mission scenarios. This

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[16] Roscoe, 1976, op. cit.

computer graphic technique, and others like it, is one of the most promising methods of teaching contour interpretation, which is the most essential and most difficult part of mission planning.

Adaptively-branching, individual-progress logic, and related CAI techniques can be applied to almost any part of the academic portions of the current curriculum. Further, a central terminal with peripherals in the operational units could be an effective aid to advance unit training, in that it would provide better standardization of instruction and would provide the flexibility and versatility that unit level training requires.

In many missions where NOE flight is employed, the initial leg will often be flown at higher altitude, with a descent to NOE at a pre-planned point. It has been known for many years that the high-to-low altitude transition is one of the most prevalent factors associated with incidents of geographic disorientation, although the reasons for this relationship have only been hypothesized.[17] That is, if a pilot becomes disoriented at NOE altitudes it is most likely to occur at the very beginning of the NOE run, unless he carefully plans and prepares for the high-to-low altitude transition. The importance of selecting an NOE entry point that will ensure precise orientation upon descent should therefore be stressed in the training program.

Route Study and Memorization

The recommendations made in the discussion of navigation and orientation training apply equally to the development of the map-interpretation skills required for preflight route study. The NOE map user's manual would provide the academic base for the training and the cinematic simulation techniques would provide practical exercises and demonstrations in man-interpretation methods. Cinematic training should place special emphasis on developing the pilots ability to predict, from maps and other sources, the appearance and characteristics of the real world as it will be seen from NOE altitudes along a given route of flight. For example, cinematic training exercises can readily be developed that exercise the student's route study skills by testing (and providing feedback on) his ability to classify features portrayed on the map along the NOE flight corridor into (1) features that will not be visible, (2) features that will be visible but difficult to identify, and (3) features that will be visible and easily identified.

Terrain sketch methods should also be explicitly taught. A simple drafting tool for preparing perspective low-altitude sketches from maps was developed by the USAF Aeronautical Chart and Information Center (now DMA Aeronautical Center) many years ago. These tools should be acquired and furnished to all Army pilots, along with instruction in their use.

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[17] McGrath and Borden, 1963, op. cit.

Special efforts should be made to enhance the ability of pilots to commit map data to memory. At present, brute force methods are the only ones used. There is no better way to develop memory skills than by practice and feedback, but this process can be expedited. The key training principle is to devise methods whereby the student is compelled to exercise his map recall and to provide him with immediate knowledge of results. For instance, the student can be presented a map plate covering part of the operating area, the plate containing a "window" or blank spot; he must then draw in the missing portion of the map and compare his recall with the actual missing window. Flash-card methods, in which an oblique photo of a landmark feature or area is shown on one side and a map plate containing the photographed feature or area is shown on the other side, can be used for impromptu or ready-room practice in map interpretation and terrain familiarization. Simple teaching machines, with no need for elaborate programming, are also useful for memory training. Mnemonic devices or "gouges" might also be developed, but we know of few good ones that apply to map recall. The best method is the terrain analogy technique, whereby the pilot deliberately notes terrain forms, vegetation patterns, shorelines, and the like, that resemble such things as a panhandle, flatiron, camel hump, human face, or other objects with easily associated shapes.

Impact of Equipment Developments

Although developments in navigation and display systems may change some of the content of mission planning, we could identify no major impact on training methods applied to daylight VFR operations. Night operations with sensor devices will require significantly different methods of terrain familiarization. Changes in tactics, particularly in multi-ship, combined arms operations, will greatly expand the subject matter content of training in mission planning.

AIRCRAFT HANDLING

Requirements

A basic set of performance requirements includes the tasks of controlling the attitude and movement of the aircraft. The specific control skills involved in NOE flight are much the same as those involved in conventional helicopter flight. They include a host of coordinated psychomotor responses and precise manual adjustments. What changes most in NOE operations are the reduced error tolerances and time constraints within which the aircraft handling skills must be exercised. Consequently, the thrust of the training requirements in this area is on increasing both the precision and speed of control responses. The aviator will already have developed elementary skills in controlling the aircraft by the time he enters NOE training. The aircraft-handling training objectives of the NOE program then should focus on three main goals: improving the speed and accuracy of the aviator's manual control, developing his ability to operate the ship within the special constraints of the NOE environment, and developing his ability to perform certain

maneuvers that are an essential part of NOE operations.

Potential methods of improving training oriented toward each of these goals are discussed below. Present training in NOE aircraft handling is done virtually exclusively through flight training, and seems to meet the performance criteria with good consistency. The main potential for improvement is in either reducing the number of flight hours required to develop these skills or in gaining increased benefits from the flight hours that are available.

Manual Control Skills

The development of increased precision of manual control, particularly of power, might be augmented through the application of moving-base simulator techniques. This type of training objective is almost a classical candidate for the application of adaptive training technology. Although all individualized training is, in a sense, adapted to the individual student's progress, the term adaptive training refers to the academic adjustment of the training task as a function of the student's automatically measured performance.[18] Development of an effective adaptive training system is a complicated process, beset with many pitfalls; but such systems are especially suited to the objective of reducing the error tolerance within which an operator can learn to perform manual control tasks. However, the potential utility of any form of synthetic flight training, adaptive or not, is limited by the motion and visual fidelity requirements of NOE training devices. Our review of training technology indicated that the motion requirements probably could be met, but the lack of truly effective methods of simulating the extra-cockpit visual field would limit the utility of simulator training. This is because the stimulus cues for manual control responses at NOE altitudes are not found in the cockpit displays but in the external world. The lack of high-fidelity methods of simulating the external world and the cost-effectiveness considerations described at some length by Roscoe[19] will probably dictate the use of part-task simulation techniques in developing increased skill in manual control.

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[18] Kelley, C. R. Adaptive and automated research techniques from engineering psychology. American Psychologist, 1969a, 24, 293-297.

Kelley, C. R. What is adaptive training? Human Factors, 1969b, 11, 547-556.

McGrath, J. J. and Harris, D. H. Adaptive training. Aviation Research Monographs, 1971, 1(2).

[19] Roscoe, 1976, op. cit.

Operating Within NOE Environmental Constraints

To develop the aviator's ability to handle the aircraft within the constraints of the NOE environment, the training program should focus on two requirements: the need to operate in close proximity to obstacles and the need to be able to perform any maneuver either upwind, downwind, or crosswind. The first requirement is considered by most instructors to be the essence of NOE aircraft handling and rightly gets central attention in present training programs. There is positively no sensible alternative to flight training for teaching the special techniques of operating in confined spaces or close to the terrain and other obstacles. The main problem is the potential impact of flight restrictions imposed for safety considerations, which limit how close the aviator may approach buildings, wires, and other objects. The operational mission requirements indicate that NOE crews will have to operate in combat much closer to obstacles than flight restrictions allow them to operate during training, and the question is whether or not the present flight restrictions constitute the best trade-off between safety and training effectiveness. We concluded from our interviews with instructor pilots that this is a highly controversial issue which warrants an objective study.

The requirement that the NOE aviator be able to handle his ship effectively under any wind condition adds up to a need for special training in downwind maneuvers. Synthetic flight trainers that incorporate the necessary forcing functions have good potential for supplementing flight training, but they must also incorporate a valid display of the extra-cockpit visual field. In addition, the flight training syllabus should be sufficiently flexible to permit impromptu scheduling of training in downwind or crosswind takeoffs, landings, and hovers when the appropriate wind forces prevail.

NOE Maneuvers

Development of skill in performing the special maneuvers that are unique to NOE operations must be a focal point of the NOE flight training syllabus, but should not be attempted too soon. One reason is that the development of skills in the other two areas of aircraft handling is, for practical purposes, prerequisite to the effective and safe development of skill in performing quick-stop, evade drop and dash, landing zone operations, and other maneuvers, including hovering in and out of ground effect. Another reason is that special NOE maneuvers are generally required as a part of tactical employment and should be taught in that context. There are no important discrepancies between the training objectives of the present program, particularly as defined in TC-1-15, and the training objectives identified in this study. However, we identified two possible problem areas that merit attention: the potential for negative transfer of training and the need for overlearning.

Negative transfer effects may impede learning of the NOE deceleration (quick stop) technique because the pivot point is shifted considerably aft of the pivot point in normal deceleration. The danger is that the

aviator, under stress or in an emergency, may regress to his previously learned normal deceleration technique and thereby incur a tail rotor strike. The Army might consider the idea of introducing the NOE deceleration technique initially so that it, in effect would become the "normal" method and would not be susceptible to negative transfer effects.

The need for overlearning is especially important in this area of training. Overlearning is an appropriate training technique whenever the operator must retain his learned skills in the absence of opportunity for interim practice. This means that the aircraft handling skills required for special NOE maneuvers must be developed to the point where the actions are second nature to the aviator and where he can execute any such maneuver with precision even though he has not recently practiced it. In addition, proficiency maintenance training programs should not be confined to the minimum qualification requirements for the most commonly used maneuvers, but should expressly include maneuvers that are rarely exercised in normal operations.

Impact of Equipment Developments

Training requirements in the aircraft handling area are likely to change as helicopters presently under development come into operational use. The conclusions of our review of these developments agree with those expressed by Weaver.[20] The increased speed of these aircraft should not adversely affect training, but might make some aspects of flight training easier by presenting fewer performance restrictions. However, the projected capability for rapid multidirectional accelerations and decelerations, or lateral agility in Weaver's terms, will require special flight training to exploit that capability. Training in precision hover out of ground effect at considerably greater gross weights will be needed for pilots of some aircraft. The introduction of new Aircraft Survivability Equipment will be accompanied by new forms of evasive maneuvers that also must be learned. But, the biggest challenge is likely to be the need to develop initial entry and transition training programs to deal with the special problems of handling multi-engine helicopters.

VISUAL SURVEILLANCE

Requirements

NOE operations require exacting performance of continuous visual surveillance tasks, both external and internal. The visual skills

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[20] Weaver, C. A. Future aircrew training requirements for rotary-wing flight. In Aircrew performance in Army aviation. Proceedings of U.S. Army Office of Research, Development, and Acquisition conference, November 27-29, 1973, Army Aviation Center, Fort Rucker, Alabama, 1974.

involved in external surveillance could perhaps be subsumed under the navigation and tactical employment categories in that the main object is the detection and identification of checkpoints, targets, and threats. But external surveillance must be closely coordinated with the performance of internal surveillance tasks, which mainly involve display monitoring and map reading, and the combined tasks demand a highly efficient visual scan. Therefore, the visual surveillance abilities of NOE flight crews had best be developed as a unitary set of skills.

Potential Improvements in Training

The present Initial Entry NOE program and the unit training curriculum described in TC-1-15 include training in visual scan techniques and some practice in target and threat detection, but it does not appear to be highly formalized. Perhaps the reason for this is that visual surveillance skills are difficult to define and generally have to be developed under field conditions.

Visual scan training should be aimed mainly at reducing "head down" time to a minimum and at developing an efficient search pattern in scanning the external world. Constant practice under actual flight conditions is the only effective means of developing this skill, because the pilot must learn to internalize the scanning rhythm so that it is automatic and smoothly coordinated with his other activities. Synthetic flight trainers are notoriously poor devices for teaching visual scanning and, in fact, may even promote detrimental scanning habits. This is because simulators cannot provide a realistic external visual field, either in size or resolution, and the operator in a simulator invariably devotes disproportional attention to the cockpit displays. Tachistoscopic devices of the type used in teaching "speed reading" are equally unpromising, because they are not suited to the dynamic visual environment of NOE flight.

On the assumption that visual scanning skills must be developed under actual field conditions, few improvements in current training practices can be made. However, the effectiveness of present training would almost certainly be enhanced if both the student and the instructor were given feedback on the student's scanning behavior. This could be accomplished most easily by mounting a Super-8mm camera and a small reflecting mirror in the cockpit so that the student's eye movements could be photographed. A frame-rate of one film frame per second would suffice to record the proportionate amounts of time the student was looking inside or outside the cockpit and the sequential scan pattern he most predominantly adopted. A single 50-foot cartridge of film would record an hour of scanning, which could be analyzed on a film editor during post-flight debriefing. A criterion film showing the scanning behavior of a highly experienced pilot could be used for comparison. Specific problems, such as excessive head-down time, or inappropriate search patterns, could be diagnosed and brought to the student's attention. Eye scan records could be made at suitable intervals during NOE training and used to track the student's progress.

Training in target and threat detection is another visual surveillance skill that must ultimately be developed through actual flight training. However, the essence of the skill is knowing what to look for and where. Consequently, there is an important role for ground training in this area. While cinematic simulation methods can be effective for teaching the checkpoint acquisition and other surveillance aspects of geographic orientation, these methods will not suffice for target and threat acquisition. The image resolution of projected films, with any reasonably adequate field of view, is simply not good enough for simulating tactical target acquisition, even when large (70mm) film formats are used. Ground school training should be devoted mainly to developing the student's understanding of the physical characteristics of tactically meaningful targets and threats; their associated cues, such as vehicle tracks, smoke, or revetments; and their most likely places of deployment. This training can be accomplished through illustrated lectures and, possibly, programmed instructional media. In this connection, we might note that the Army's existing programmed texts on aerial observation are of doubtful value, because the illustrated observation altitudes are significantly higher than those that prevail in modern NOE operations and present-day targets of interest are not included. It is highly important that academic training in target and threat acquisition remain flexible and responsive to changes in the weapons and tactics of potential adversaries.

CREW COORDINATION

Requirements

NOE flight is not a one-man job. Many of the tasks identified in the analysis require coordinated performance of crew members, therefore the development of team performance proficiency is a mandatory part of NOE flight training. The required degree of coordination and the specific teamwork techniques vary as a function of the type of helicopter and the type of operation or mission to be accomplished; but crew coordination is generally most important during NOE navigation and during engagement. While the team tasks that must be accomplished may apply to areas already discussed, such as navigation, the coordination skills required to perform them might be considered as a separate training requirement.

The instructor pilots whom we interviewed were unanimous in their view that combat effectiveness of NOE crews can be achieved only when the crews unite in a smoothly coordinated team effort, both between the pilot and copilot of a given aircraft and between the crews of different aircraft. However, there was little agreement on how best to develop the crew's ability to work together.

Potential Improvements in Training

The importance of crew coordination is stressed in the current Initial Entry NOE training and in the curriculum described in TC-1-15.

Both the attitudes and the skills required for effective NOE teamwork must be developed from the earliest phase of NOE training and sustained throughout all subsequent NOE training. This philosophy is reflected in the current training programs, but the training itself is not explicit. Our impression is that much of the required coordination is expected to evolve from experience rather than be directly taught. To some extent this is inevitable (and desirable) as aviators learn each other's capabilities, language, and operating traits to the point where each man can anticipate his partner's actions, intentions, or needs.

We do not know what might be done to improve or facilitate the development of crew coordination skills. In other areas of human performance where teamwork is a central requirement, the best training method has been to clearly delineate the workload distribution, define the task procedures "by the numbers," then practice and drill. This may be the best approach in NOE training as well. But the task allocations in NOE operations are not that cut and dried; a good deal of impromptu task sharing necessarily takes place; so drill alone will not suffice. Improvements in crew coordination training can best be developed from a better understanding of NOE crew workload than now exists. At present, not even an acceptable method of defining or measuring workload has been developed. Recommendations in this area cannot be made without further research.

COMMUNICATIONS

Requirements

The results of the operational task analysis showed that NOE flight requires the performance of a great many communications tasks. In fact, these tasks constitute the decisive factor in the total workload imposed on the flight crew during NOE operations. The communications load is heaviest on the pilot/commander, who not only conducts all external radio communications, but must engage in a continuous exchange of information with the copilot/observer/gunner.

Under combat stress or task overload, communications performance typically is the first crew function to deteriorate. At the very time that clear, concise, accurate communication is most needed, communication discipline is most apt to break down and crew members are most likely to neglect the exchange of information. When many elements are involved in a combined arms operation, the communications problems multiply. Ketchel and McGrath[21] found, for example, that the most prevalent problems in close air support missions in Southeast Asia were communication problems

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[21] Ketchel, J. M., and McGrath, J. J. A study of airborne forward air control, Volume I. China Lake, California: U.S. Naval Weapons Center, Code 4011, NWC TP 5537, 1973. (CONFIDENTIAL)

such as crowding of radio frequencies, unnecessary chatter, malfunctioning of secure voice equipment, inadvertent interference by other units, and numerous radio discipline problems. Many of the communications problems in tactical NOE operations can be resolved through technological improvements in equipment, but much can be accomplished through training.

Potential Improvements in Training

Training in this area should be directed toward two basic communications skills: the ability to formulate and transmit a relevent, accurate, intelligible message and the ability to understand and follow the correct communication procedures. Almost all existing training in NOE communications is aimed at the latter, procedural skill; training in the former is not an explicit part of Initial Entry or unit level curricula, but is given in an informal way as a part of other subjects, such as NOE navigation.

Procedural Skills. The procedural skills can be developed well enough by present methods, which include academic instruction and field practice. The curriculum outlined in TC-1-15 covers most of the training objectives in communications procedures that we identified. The importance of the problem, more than any particular deficiency in the present training, indicates the need for improvements in this area.

The application of simulation techniques is highly promising and we recommend that it be pursued. Synthetic flight training is most effectively applied to the development of procedural skills of the type required here. Simulation of virtually all of the relevant elements of the procedural tasks in NOE communications is well within the state of the art, and can be accomplished without elaborate instrumentation. However, imaginative methods need to be developed to establish a meaningful situational context for simulator training in communications procedures.

This application of simulation would provide a cost-effective supplement to flight training, because it can be directed at two important requirements: standardization and proficiency maintenance. Simulator exercises are better than field training in promoting standardized performance of procedural tasks. Consequently, the application of simulator methods to teaching communications procedures would be especially valuable in advanced unit-level NOE training programs, because simulator training programs can readily be standardized on a common core of instruction. Simulator training would also be highly useful in proficiency maintenance, because procedural skills, as opposed to psychomotor or cognitive skills, are the first to deteriorate with disuse. When the requirement is to maintain skills in following standardized procedures, the need for refresher training is even more important. Refresher training in procedural skills by means of lectures or academic instruction is futile, and refresher training by means of field exercises in all the many aspects of NOE communications would be prohibitively expensive. The use of special-purpose simulators accompanied

by carefully developed programmed instruction and drills would be the most cost-effective approach to proficiency maintenance in this area.

Cognitive Skills. The other aspect of communication skill--the ability to formulate and transmit an effective message--presents a challenging training problem. This skill represents an exceptionally high and complex order of cognitive functioning, involving perception, concept formation, decision-making, verbalization, enunciation, vigilance, audition, attention sharing, memory, and judgment. Some elements of the skill, such as proper enunciation, can be developed readily enough with simple training methods. Other elements, such as verbalization, can be improved by developing better operational procedures. For example, the communication of navigation information between the pilot and copilot could probably be made more efficient and less ambiguous if the Army developed and used a standard lexicon of terrain and map information. But the central problem is teaching aviators to recognize relevant information that needs to be communicated and to formulate and transmit the message in a concise, complete, intelligible manner. Simulator techniques are of doubtful value because the task demands a complete mission context, which can never be achieved through synthetic flight training techniques. The approach must be to seek greater training dividends from field exercises, particularly those in which meaningful battlefield simulations are employed. For example, tape recordings of all internal and external communications could be made during the exercise and subjected to a detailed post-flight review and critique. The purpose of the critique would be to identify and diagnose such problems as failure to communicate a relevant message, untimely communication, garbled syntax, unintelligible speech, misunderstandings, misattributions, and the like. (In addition, procedural errors and violations of communications discipline could be identified.) But this technique, or others like it, would have maximum training value only if the instructors were given clear guidelines to help them identify and diagnose both good and poor communications. We recommend that a study of NOE communications be performed to develop such guidelines.

Some form of training in performance under stress is needed to fully develop skill in NOE communication tasks. Operational experience has always been the best teacher of controlled responses to hazard stress, because experience inures emotions and builds confidence. While there is no real substitute for operational experience in developing the aviator's ability to perform under hazard stress, synthetic flight training methods can be applied to train him to deal more effectively with workload stress. Adaptive training techniques, in which the rate of non-communication task demand is the adaptive variable, could be used to train aviators in performing communications tasks under high workload stress.

EMERGENCY PROCEDURES

Requirements

We classified the skills required to deal with emergency events in a separate category, even though they largely comprise many of the skills that were classified in the visual surveillance and aircraft handling categories. We did this because the skills required to detect, diagnose, and react to system malfunctions and other emergencies must generally be developed as highly organized patterns of perceptual, cognitive, and motor responses. That is, the detection of the emergency might involve visual skills and the response to it might involve a combination of crew coordination, tactical decision-making, and aircraft handling skills, but the total performance must be a coherent whole.

NOE flight conditions impose at least three classes of training requirements beyond the conventional training of helicopter crews in contingency performance: (1) understanding of NOE hazards, (2) performance of low-altitude recovery maneuvers, and (3) execution of rapid, error-free responses.

Potential Improvements in Training

<u>NOE Hazards</u>. Army aviators engaged in NOE operations must learn to detect and recognize hazards and emergency conditions that are not encountered at higher altitudes or which have less serious implications at higher altitudes. This requires a thorough understanding of the NOE environment and the hazards it contains, an understanding of the capabilities and limitations of both the aircraft and the crew as they apply to NOE flight conditions, and a current knowledge of the special safety regulations and practices that apply to NOE operations. In fact, it may be fair to say that NOE crews need to adopt a whole new attitude toward safety.

The present training programs, at both entry and unit levels, place very strong emphasis on flight safety. In a sense, the emphasis might even be too strong. Safety restrictions and practices that prevail in NOE flight training tend to sanitize the environment and make it less representative of the combat operations for which Army aviators are to be trained. For example, all NOE flight training routes are carefully inspected for hazards, such as wires, and an accurate, current hazard map is prepared and posted. Similarly detailed hazard maps would not be available in actual combat operations. This is not to suggest that such safety procedures be abandoned, but only that the increased safety may come at a cost in the aviator's ability to operate in a more hazardous environment. Generally, the present training program needs little improvement in this area

<u>NOE Recovery Maneuvers</u>. The altitudes, attitudes, and speeds that prevail in NOE operations require some special aircraft-handling skills. Skill in performing maneuvers such as low-level autorotations can be developed only through actual practice under a variety of altitude and

speed conditions. The skill must be developed in the earliest part of NOE flight training and maintained throughout the aviator's flying career. The flight time allocated to this type of training in the current program is skimpy and should be increased.

Reaction Time. The key difference between many of the emergencies that occur in NOE operations and those that occur at altitude is that the NOE pilot has considerably less time to detect, diagnose, and respond to the problem. Consequently, the most important aim of training in this area is to reduce reaction time to a minimum and response-error rates to zero. To accomplish this end, aviators must actually be overtrained in detecting cues to an incipient emergency, validly diagnosing the problem, choosing the best action option, and executing the action with speed and accuracy. The main limitation of present training is that it places greater emphasis on the pilot's ability to state, explain, or list emergency actions than it does on his ability to perform them. This is a consequence of the fact that training in emergency responses is both difficult and dangerous in an aircraft. However, the results of our analysis of contingency performance requirements indicated that the main cues and almost all responses, except landing site selection, can be incorporated into synthetic flight training with systems such as the Army's SFTS Device 2B24. An expanded role for this device is clearly warranted in developing the pilot skills in this area.

SYSTEMS MANAGEMENT

Army aviators need a wide range of technical knowledge and skill to manage and operate the various systems and subsystems onboard their aircraft. Many of the performance problems in this area can be attributed largely to the design of the systems or the crew station, but proficiency maintenance in this area can be a significant training problem. Since most of the skills and knowledge involved in systems management are of the procedural type, the training objectives can largely be achieved through the use of simulators. However, we did not identify any specific deficiencies in the current training program in this area, and other than the general observation that synthetic training devices could be more extensively used, we have no recommendations to offer.

TACTICAL EMPLOYMENT

Requirements

The ultimate criterion of the performance of Army aircrews is their ability to engage their aircraft/weapon system in tactical employment in combat, including combined arms operations with multiple air and ground units. Judgment, decision-making, ingenuity, and other cognitive performance requirements are key elements, as are the perceptual/motor skills and technical knowledge that are components of the other classes of performance that have been discussed in the preceding sections. But

in this aspect of aircrew performance, the ultimate level of effectiveness is often determined by valor, audacity, fortitude, enterprise, resourcefulness, and even cunning. These traits are not necessarily related to the technical skills of airmanship, and they are not the kinds of things that scientists can measure and instructors can teach. In a sense, training in tactical employment must always be done on the theoretical level, because the actual application is situation-specific.

Potential Improvements in Training

All of the preceding classes of performance are components of this one, and to the extent that improvements are made in those areas, skill in tactical employment should be improved. But these component skills must come together in a coherent whole if the aircrew is to be operationally effective. We believe that the main deficiency in this area is not so much a shortcoming in training methodology as a lack of tactical doctrine. A vagueness of purpose now exists in aircrew training programs dealing with NOE tactics, and this needs to be remedied before effective training methodology could be developed.

TECHNICAL SUPPLEMENT

ANALYSIS OF OPERATIONAL TASK REQUIREMENTS

The most important step in developing statements of training requirements is to specify the operational tasks that must be performed. These task requirements define the skills and knowledge that an aviator must possess to be a member of an operationally qualified aircrew. Therefore, the first major part of this study was an analysis of the aircrew tasks that must be performed to accomplish the requirements of Army aviation missions in which NOE flight tactics would be employed.

Method

Each step of the task analysis was accomplished with the help of experienced Army pilots from operational units. A total of 30 pilots participated in various phases of the analysis to ensure the accuracy of the task descriptions and to verify the operational relevance of the results. The task analysis procedures and their relationship to the analysis of training requirements are outlined in flow-chart form in Figure 2.

The information sources for the task analysis consisted of operator's manuals, published statements of tactics and doctrine, and numerous interviews with experienced pilots. The pilot interviews consisted of a series of increasingly detailed and structured interrogatories.

The analysis proceeded in successive levels from the general to the specific, so that each succeeding specification was set in its larger operational context. The successive levels of the analysis were:

> Battle scenarios. General scenarios were developed which defined representative battle environments in which Army helicopters would be employed in offensive and defensive operations. The battle scenarios defined the terrain, the deployment of forces, and the resources of enemy and friendly units.
>
> Mission scenarios. Within a defined battle environment, scenarios were developed to describe the mission objectives to be accomplished by the aircrew. Representative scenarios were developed for anti-armor, ground troop support, reconnaissance, and medevac missions to be undertaken by attack, utility and scout aircraft. Each scenario defined the battle situation, mission objectives, and other information characteristically contained in operational orders. Brief scripts were then prepared to describe the course of events on the missions.

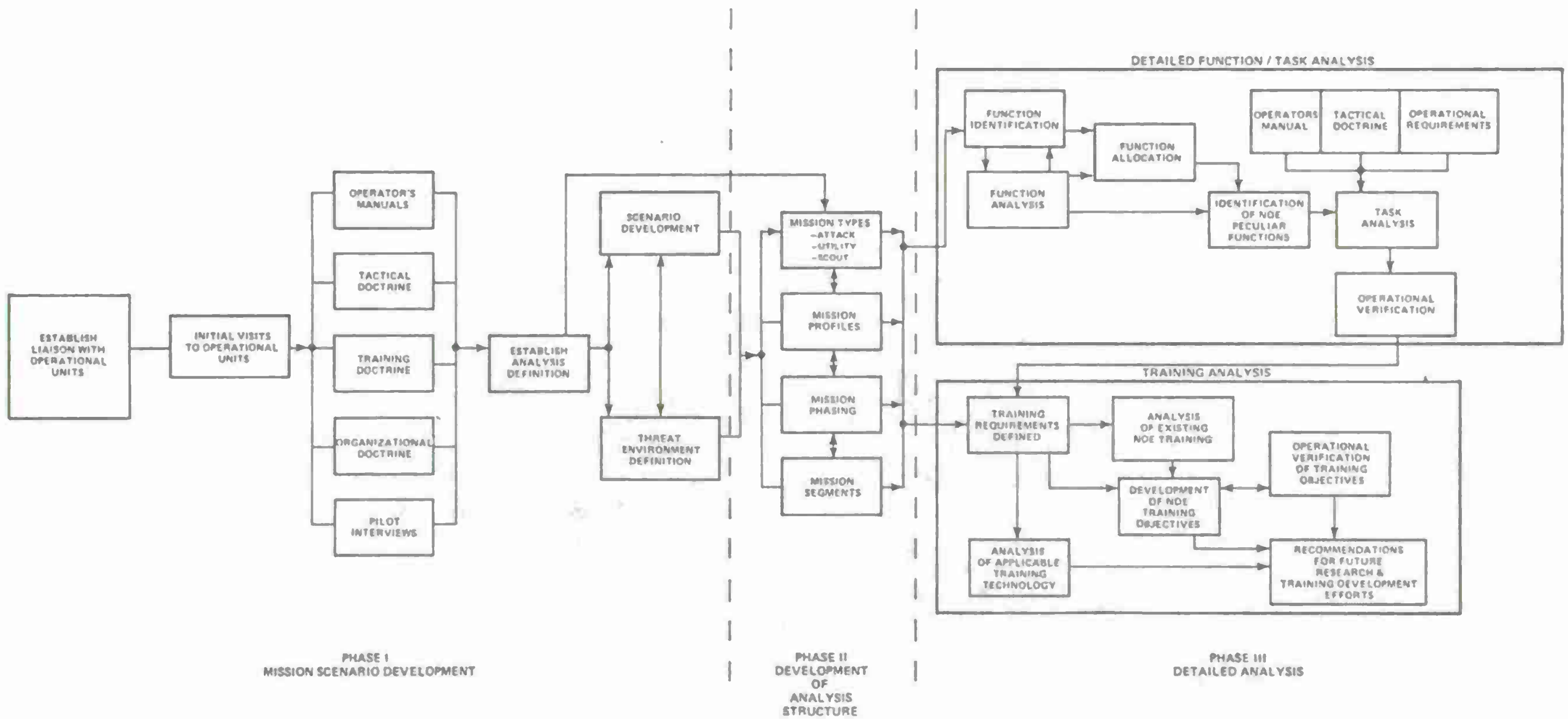

Figure 2. Operational requirements analysis process

Mission profiles. Altitude and airspeed profiles and course plots were determined for each mission scenario, based on the mission requirements, type of aircraft employed, and the terrain characteristics. The course of events on each mission was then described briefly on a time-line chart to indicate the probable time constraints on aircrew performance.

Mission phases and segments. The main sections of the mission profile and sequence of events were identified to define the mission phases that would be most meaningful in structuring the task analysis. The mission phases were then divided into segments which defined the principal tasks that must be accomplished in each phase.

Functions. The aircrew functions that must be accomplished in each mission segment were then identified. A "function" was taken to be a single action or a set of actions that produces a coherent outcome that is essential to the successful performance of a mission segment. We also identified any subsystem or equipment that must be operated in accomplishing each function and specified the aircrew member who normally had primary responsibility for the function. The identified functions, listed in the general sequence in which they occur in a mission, are given in detail in a separate report.[22] Of 129 functions identified in the analysis, 70 were found to be peculiar to, or performed differently in, NOE flight. The mission phases, segments, and functions are outlined in Table 1.

Tasks. The final level of analysis was to identify the aircrew actions and activities, or tasks, that must be performed to accomplish each of the functions. These tasks were specified in considerable detail using the analysis form illustrated in Figure 3. A total of 1,078 explicit task requirements were identified.

A special analysis was conducted to define the performance requirements associated with the detection, diagnosis, and response to emergencies and contingencies that can occur during NOE flight. In general, these emergencies and contingencies are the same types of critical events that can be encountered during operations at higher altitudes, but they often must be handled differently. As a consequence of operating in close proximity to the ground and obstacles, the time available for recognizing and responding to an emergency condition is greatly reduced during NOE operations. In fact, all aircraft presently in the inventory are operating either outside or at the limits of their specified performance envelopes during NOE flight, which further restricts the pilot's options and time available for response.

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[22] Gainer and Sullivan, 1976, op. cit.

Table 1

OUTLINE OF MISSION PHASES, SEGMENTS, AND AIRCREW FUNCTIONS

A. PREFLIGHT	B. DEPARTURE	C. ENROUTE	D. ENGAGEMENT	E. RETURN TO BASE	F. TERMINATION	G. CONTINGENCIES/ EMERGENCIES
1. MISSION PLANNING 1.1 Receive In-Depth Briefing 1.2 Select Maps 1.3 Map Interpretation 1.4 Receive Weather Briefing 1.5 Determine Route of Flight, Checkpoints, Phase lines, Comm. Control points. 1.6 Select Attack Position 1.7 Determine Maneuver (Battle) Area 1.8 Select Observation Positions 1.9 Select Aerial Firing Positions 1.10 Select Landing Zones 1.11 Select Entry Routes 1.12 Select Exit Routes 1.13 Determine ground to air and air to air SOI's to be used during mission 1.14 Determine Max. Flight Altitude 1.15 Calculate Estimates 1.16 Determine Fuel Requirements 1.17 Select Armament 1.18 Calculate Weight and Balance 1.19 File Flight Plan **2. MISSION COORDINATION** 2.1 Brief Crew 2.2 Brief Passengers 2.3 Establish Inflight Coordination system between crew members **3. A/C PREFLIGHT** 3.1 Before Exterior Check 3.2 Exterior Check Right Side 3.3 Exterior Check Left Side 3.4 Armament Check 3.5 Interior Check Pilot 3.6 Interior Check Copilot **4. SYSTEMS CHECKS** 4.1 Start Engine 4.2 Perform Engine Runup 4.3 Electrical System Checks 4.4 Navigation System Check 4.5 Weapon Systems' Check 4.6 Fuel System Check 4.7 Communication System Check 4.8 Flight Controls Check 4.9 Hydraulic System Check 4.10 Lights Check 4.11 SCAS Check 4.12 De Ice Systems Check 4.13 ECU System Check 4.14 Pitot Heater Check 4.15 Cockpit Console(s) Check 4.16 Engine and Flight Instruments Check 4.17 Check Passengers 4.18 Check Cargo	**1. HOVER** 1.1 Departure Clearance—Comm. 1.2 Complete Pre Hover Check 1.3 Hover Taxi Aircraft 1.4 Hover Aircraft 1.5 Check Flight Instruments 1.6 Check Engine Instruments 1.7 Check Flight Controls 1.8 Join-Up Multi-Ship **2. TAKE-OFF** 2.1 Comm. Unit Operations/ Tower 2.2 Pre-Take Off Check 2.3 Aircraft Take-Off 2.4 Monitor Instruments/ Airspace 2.5 Climbout **3. LEVEL OFF** 3.1 Normal Cruise 3.2 Comm. Departure Control 3.3 Perform Level Off Check/ Activate ECU 3.4 Monitor Instruments & Airspace	**1. NOE FLIGHT** 1.1 Determine Position 1.2 Monitor/Adjust Airspeed 1.3 Monitor/Adjust Altitude 1.4 Monitor/Adjust Heading 1.5 Monitor Instruments 1.6 Monitor Airspace 1.7 Maintain Mask 1.8 Maintain Obstacle Clearance 1.9 Monitor Obstacle Clearance 1.10 Perform Intersection 1.11 Use Barriers 1.12 Interpret Terrain 1.13 Crew Coordination 1.14 Comm. Position/Clearance	**1. MANEUVERS** 1.1 Pop up Maneuver 1.2 Mask Maneuver 1.3 Evasive Maneuver 1.4 New OP Maneuver **2. PRE-ATTACK** 2.1 Comm. Contact 2.2 Arrive Attack Position 2.3 Perform Hover Check/Hover/ Land A/C 2.4 Activate Weapons System 2.5 Verify Position/Routes/ Confirm OP 2.6 Maneuver into OP 2.7 Comm. Position OP 2.8 Hover and Check Instruments **3. TARGET ACQUISITION** 3.1 Receive Target Data 3.2 Pop Up Maneuver 3.3 Perform Visual Search 3.4 Detect Target 3.5 Identify Target 3.6 Locate Target 3.7 Mask Maneuver **4. WEAPONS DELIVERY** 4.1 Attack Target 4.2 Hover Fire 4.3 Running Fire **5. MANEUVER** 5.1 Mask Maneuver 5.2 Maneuver to New Position **6. ENEMY DETECTION** 6.1 Receive Enemy Detection 6.2 Receive Hit/Assess Damage 6.3 Evade Dash 6.4 Evade Drop 6.5 Comm. Report Enemy Detection	**1. DEPART MANEUVER AREA** 1.1 Navigate NOE 1.2 Determine Flight Route **2. CRUISE** 2.1 Cruise NOE	**1. APPROACH** 1.1 Pre-Landing Check 1.2 Perform Landing 1.3 Terminate Landing **2. HOVER** 2.1 Hover/Taxi 2.2 Hot Refuel **3. POST FLIGHT** 3.1 Aircraft Shutdown 3.2 Perform A/C Post Flight Check 3.3 File After Action Report/ Debrief	**1. EMERGENCY PROCEDURES** 1.1 Recover from Spatial Disorientation 1.2 Engine Failure 1.3 Short Shaft Failure 1.4 High Side Govenor Failure 1.5 Low Side Govenor Failure 1.6 Inlet Guide vanes closed 1.7 Tailrotor Failure 1.8 Compressor Stall/Power Surge 1.9 Aircraft Fire 1.10 Cockpit Smoke, Fire or Fumes 1.11 Blade Strike 1.12 Sluggish Flight Controls 1.13 Hydraulic Failure 1.14 Chip Detector 1.15 D.C. Generator Failure 1.16 Clogged Fuel Filter 1.17 Engine Oil Bypass Flight 1.18 Transmission Oil Bypass 1.19 A.C. Inverter Failure 1.20 Fuel Boost Pump Failure 1.21 SCAS Failure (Hardover) 1.22 Engine Icing (Airscreens)

AIRCREW FUNCTIONS IN NOE OPERATIONS

TASK ANALYSIS

MISSION PHASE: EN-ROUTE
FUNCTION: MONITOR/ADJUST ALTITUDE

SEGMENT: CRUISE NOE
SUBSYSTEM: FLIGHT CONTROL

Task: Verb	Task: Object	Task: Modifier	Operator Action	Control/Display: Name	Control/Display: Options	Equipment Resp.	Task Type	Feedback: V	Feedback: A	Feedback: Other	Stimulus Input	Operator Decision Options	Crit. Resp.	Accuracy Required	Comments
1. ADJUST	CONTROL	COLLECTIVE	ACTUATE CONTROL TO ACHIEVE MAIN ROTOR BLADE PITCH ATTITUDE REQUIRED FOR DESIRED ALTITUDE	COLLECTIVE CONTROL	UP-DOWN	TILTS MAIN ROTOR BLADE ANGLE IN DIRECTION OF APPLIED FORCE (PITCH) (TORQUE)	D	✓			VISUAL (EXTERNAL) ALTIMETER	MAY ACTUATE CONTROL UP OR DOWN, INCREASE/DECREASE TORQUE	1		MUST ACTUATE CONTROL APPROPRIATE TO ACHIEVE DESIRED ALTITUDE AND AVOID A/C IMPACT WITH OBSTACLES OR THE GROUND
2. MONITOR	AIRSPACE		OBSERVE: 1) TERRAIN AND AIRSPACE AROUND HELO TO IDENTIFY POTENTIAL FLIGHT HAZARDS AND REMAIN BELOW SURROUNDING TERRAIN FEATURES FOR MASKING EFFECT; 2) OTHER AIRCRAFT; 3) BIRDS	NONE	N/A	N/A	C	✓			EXTERNAL VISUAL	NONE	1		MUST DETECT, IDENTIFY AND EVALUATE AIRSPACE AND TERRAIN OBJECTS AND FEATURES THAT COULD BECOME POTENTIAL FLIGHT HAZARDS AND/OR UNMASK THE AIRCRAFT
3. MONITOR	ALTIMETER		MONITOR A/C ALTIMETER	ALTIMETER DISPLAY	N/A	ALTIMETER DISPLAY FLUCTUATES IN ACCORDANCE WITH ALTITUDE CHANGE	D	✓			ALTIMETER DISPLAY	NONE	2		MUST DETECT AND INTERPRET DISPLAY CORRECTLY TO PRECLUDE IMPACT OF A/C WITH GROUND
4. ADJUST	PEDALS	AFT ROTOR	ACTUATE APPROPRIATE PEDALS TO ACHIEVE A/C HEADING AND TRIM	AFT ROTOR PEDALS	LEFT: IN-OUT RIGHT: IN-OUT	ALTERS PITCH OF AFT ROTOR (TRIM)	D	✓			VISUAL (EXTERNAL) HEADING INDICATOR ATTITUDE INDICATOR, BALL & NEEDLE	MAY ACTUATE EITHER PEDAL IN OR OUT	1		MUST ACTUATE PEDALS APPROPRIATELY TO MAINTAIN/CORRECT A/C HEADING AND TRIM

Figure 3. Illustrative example of mission task analysis format.

In order to identify these performance requirements, we analyzed all emergencies and contingencies that could occur in the UH-1, OH-58A, AH-1G, and CH-47 helicopters. A total of 23 contingencies were found to be especially critical in NOE flight. The task analysis form for contingency performance requirements is illustrated in Figure 4 and is discussed below.

Format

The aircrew tasks were specified and organized according to the mission phase and segment in which the tasks normally are performed and according to the function that is accomplished by a given set of tasks. Each task is stated in a standard verb-object modifier form, followed by a brief description of the actions that are required in performing it. Any controls or displays that must be operated or used in performing the task are identified, and the possible control settings or adjustments are listed. The outcome or effect of the task is described in terms of the subsystem response. Each task is classified according to whether it is performed as a continuous activity or as a discrete action. The type of stimulus input to the operator performing the task is listed, and the type of sensory feedback that allows him to determine the adequacy of his response is identified. The possible decision options that the operator can take as a result of the stimulus input and feedback are identified and listed. The criticality of the task performance is rated in terms of whether or not successful performance is vital to the primary mission objective and whether or not the task must be performed at a precisely constrained moment or sequence in time. Finally, the accuracy requirements or other standards of performance effectiveness are specified where such criteria are meaningful and could be determined.

The contingency performance requirements are specified and organized in a different format, as illustrated in Figure 4. Each set of performance requirements is organized according to the source of the emergency, such as a blade strike or a particular type of system failure. Listed first are all of the available cues that can alert the pilot to the presence and nature of the contingency event. These cues are classified by the sensory process (visual, auditory, kinesthetic, etc.) that discerns them and are numbered in order of precedence. The decision options open to the pilot are listed, including any diagnostic decisions he may have to make. The principal considerations that must be taken into account are listed for each option or diagnosis. Finally, the perceptual and motor response requirements are specified. These are the things that the pilot must perceive and do to recognize the presence and nature of the contingency and to deal with it.

CONTINGENCY: TAIL ROTOR FAILURE							
AVAILABLE CUES				DECISION OPTIONS	COMMENTS	RESPONSES	
VISUAL	AUDITORY/OLFACTORY	TACTILE/PROPRIOCEPTIVE	KINESTHETIC			PERCEPTUAL	MOTOR
3 AIRCRAFT HEADING 4 TRIM BALL (ABOVE 30 KTS) 4 NOSE LOW ATTITUDE	1 POSSIBLE NOISE FROM FAILURE	1 PEDALS JAMMED 1 PEDALS FREE MOVING	2 AIRCRAFT YAW 2 AIRCRAFT ROTATION 2 AIRCRAFT ROLL 2 AIRCRAFT PITCH ATTITUDE	(1) LAND IMMEDIATELY A) PERFORM AUTOROTATION	(1A) COMPLETE LOSS OF TAIL ROTOR THRUST (HOVER AND IN FLIGHT) LOSS OF TAIL ROTOR COMPONENTS (HOVER AND IN FLIGHT) LOSS OF TAIL ROTOR PITCH CONTROL (HOVER)	(1A) RECOGNIZE TAIL ROTOR FAILURE. DETERMINE PITCH ATTITUDE REQUIRED. EVALUATE LANDING ZONE. SELECT PITCH-PULL ALTITUDE. EVALUATE TOUCH-DOWN CRITERIA.	REDUCE THROTTLE TO ENGINE IDLE. ADJUST OR MAINTAIN PITCH ATTITUDE. ADJUST COLLECTIVE PITCH TO MAINTAIN ROTOR RPM. OBSERVE ROTOR RPM. OBSERVE RATE OF DESCENT AND RATE OF CLOSURE. INCREASE COLLECTIVE PITCH. ADJUST OR MAINTAIN PITCH ATTITUDE (AIRCRAFT LEVEL).
				B) PERFORM POWER ON APPROACH	(1B) JAMMED TAIL ROTOR PITCH CONTROL (HOVER)	(1B) RECOGNIZE TAIL ROTOR FAILURE. SELECT LANDING ZONE.	ADJUST COLLECTIVE AND THROTTLE TO ADJUST/MAINTAIN ALTITUDE AND HEADING CONTROL.
						DETERMINE TORQUE SETTING AND RPM REQUIRED TO MAINTAIN HEADING CONTROL.	ADJUST CYCLIC TO MANEUVER AIRCRAFT TO LANDING ZONE.
						SELECT TOUCH-DOWN POINT.	ADJUST THROTTLE AND COLLECTIVE TO ACCOMPLISH LANDING.
				(2) RETURN TO BASE PERFORM POWER ON APPROACH	(2) LOSS OF TAIL ROTOR PITCH CONTROL (IN FLIGHT) A) PEDALS JAMMED B) PEDALS FREE MOVING	(2) RECOGNIZE TAIL ROTOR FAILURE.	OBSERVE TORQUE SETTING. OBSERVE AIRSPEED.
						DETERMINE TORQUE SETTING AND AIRSPEED REQUIRED FOR LEAST AGGRAVATED CONDITION.	ADJUST COLLECTIVE PITCH AND CYCLIC TO DESIRED SETTINGS.
						SELECT FLIGHT ROUTE.	MANEUVER AIRCRAFT TO LANDING ZONE (RUNWAY).
							PERFORM LANDING [SEE (1B).]

Figure 4. Illustrative example of contingency analysis format.

Results

The analysis of operational requirements resulted in the specification of 1,078 aircrew tasks and 23 contingency performance requirements, which are presented in a separate report.[23] These task-analysis data constitute the most exhaustive specification of NOE aircrew performance requirements that has yet been developed. Although we developed these specifications for the express purpose of deriving statements of training requirements, the data can serve as a reference source for other applications, such as developing performance assessment criteria, analyzing aircrew workloads, and developing or validating aircrew selection methods. To a more limited extent, the data can also serve as a reference source for studies of information display requirements and crew station configuration requirements.

ANALYSIS OF TRAINING REQUIREMENTS

The analysis of NOE aircrew training requirements was accomplished in the following steps: training objectives were derived from the operational task requirements; the objectives were verified by operational personnel and compared with those of existing NOE training programs; and the results of parallel reviews of training technology and systems developments were used to help draw conclusions concerning potential improvements that could be made in NOE aircrew training. The various steps of the analysis are described below.

Specifications of NOE Training Objectives

The detailed specifications of aircrew task requirements and contingency performance requirements provided the data base for identifying the training objectives that would have to be met to achieve aircrew proficiency in NOE operations. Each aircrew task and contingency performance requirement was examined in terms of its uniqueness to NOE operations or the degree to which it is performed differently at NOE altutudes than at higher altitudes. For each NOE-relevant task that was identified, the end product or outcome behavior was defined which would demonstrate an aviator's capability to perform that task. When quantitative criteria of the adequacy of performance could be identified, these were noted as potential standards for performance assessment.

These descriptions of end-product performance capabilities are the training objectives, which are arrayed in the mission phase/segment/function format so that they can be related to the task-analysis data from which they were derived (Figure 5), and listed in full in a separate report.[24]

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[23] Gainer and Sullivan, 1976, op. cit.

[24] Gainer and Sullivan, 1976, op. cit.

OBJECTIVES		PERFORMANCE CRITERIA
C.	ENROUTE	
C.1	MONITOR/ADJUST AIRSPEED	
C.1.1	The aviator will demonstrate his ability to accurately navigate within the airspeed envelope that his assigned aircraft and mission require during NOE flight.	Continuous knowledge of relative position ± 100 meters during NOE flight at airspeeds assigned by the Instructor Pilot.
C.1.2	The aviator will demonstrate his ability to adjust his airspeed at NOE altitudes to the terrain conditions of the area he is operating in.	
C.2	MONITOR/ADJUST ALTITUDE	
	The aviator will be able to select, adjust, and maintain the aircraft at a prescribed altitude above the terrain.	As close to earth's surface as terrain features and vegetation allow, and as low as the tactical situation requires.
C.2.1	The aviator will be able to list the altitude restrictions applicable to NOE operations in his aircraft.	
C.2.2	The aviator will identify the types of terrain obstacles/flight hazards common to the environment in which he is/will be flying and will be able to describe the action to be taken to clear these obstacles.	
C.2.3	The aviator will describe the limits and accuracy of the altitude sensing systems in his aircraft and describe the procedure for checking those systems prior to flight (including radar altimeter if installed).	
C.2.4	The aviator will be able to describe the external visual cues to be used in maintaining his aircraft at NOE altitudes in mountainous terrain, rolling hills, and flat lands.	
C.2.5	The aviator will be able to execute a quick stop into the wind without changing altitude.	Quick stops will terminate in a hover and will not result in the aircraft rising above the terrain features being used for masking.
C.2.6	The aviator will be able to execute a downwind quick stop without changing altitude.	

Figure 5. Illustrative example of training objectives format.

Verification by Operational Personnel

The lists of training objectives, along with the task-analysis data, were delivered to operational units at Fort Ord, Fort Bragg, Fort Knox, and Fort Hood and to NOE flight instructors at the Army Aviation School at Fort Rucker. They reviewed both sets of data and verified the accuracy and relevance of almost all of the items in the lists of objectives. They suggested several changes and a few additions, which have been incorporated into the final lists.

Comparison of Derived Training Objectives with Present NOE Training

Concurrently with the task analysis and the derivation of training objectives, we reviewed the NOE training programs of the U.S. Army and the Canadian Forces. This was done through on-site visits, interviews with instructors, and examination of curricula, syllabi, and lesson plans. We then compared the training objectives that were derived from the operational task analysis with the stated objectives of the NOE training provided in the Initial Entry Rotary Wing training program at the Army Aviation School, the individual and unit NOE training programs described in TC-1-15, and the NOE training provided in the reconnaissance helicopter pilot training program of the Canadian Forces. We also examined the objectives of the NOE flight training programs of the 1st/9th Cavalry at Fort Hood, the 7th/1st Cavalry at Fort Knox, and the night NOE programs associated with the U.S. Army Combat Developments Experimentation Center's Experiments 43.6 and 43.7, but the objectives of these programs were not sufficiently explicit to permit a useful comparison.

Reviews of Training Technology and New Developments

We reviewed the available and potential training devices and techniques that might be applied to NOE training,[24] as well as significant developments in helicopter systems and equipment that might change NOE training requirements in the future.

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[24] Roscoe, 1976, op. cit.

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